



AF
M

Docket 86583PAL
Customer No. 01333

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re Application of
Joseph F. Bringley, et al

INKJET MEDIA WITH SMALL
AND LARGE SHELLLED
PARTICLES

Serial No. 10/622,229

Filed 18 July 2003

Group Art Unit: 1774
Examiner: Pamela Schwartz

I hereby certify that this correspondence is being
deposited today with the United States Postal Service
as first class mail in an envelope addressed to
Commissioner For Patents, P.O. Box 1450, Alexandria,
VA 22313-1450.

Valerie J. Richardson
Valerie J. Richardson

November 10, 2006
Date

Mail Stop APPEAL BRIEF-PATENTS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA. 22313-1450

Sir:

AMENDED APPEAL BRIEF PURSUANT TO 37 C.F.R. 41.37

IN RESPONSE TO

NOTIFICATION OF NON-COMPLIANT APPEAL BRIEF

In response to the Notification of Non-compliant Appeal Brief mailed
October 10, 2006, submitted herewith is an amended Appeal Brief which corrects
the defects noted.

Respectfully submitted,

Andrew J. Anderson/vjr
Telephone: 585-722-9662
Facsimile: 585-477-1148
Enclosures

Andrew J. Anderson

Attorney for Appellants
Registration No. 33,564

If the Examiner is unable to reach the Applicant(s) Attorney at the telephone number provided, the
Examiner is requested to communicate with Eastman Kodak Company Patent Operations at
(585) 477-4656.

Table Of Contents

<u>Table Of Contents</u>	i
<u>Real Party In Interest</u>	1
<u>Related Appeals And Interferences</u>	1
<u>Status Of The Claims</u>	1
<u>Status Of Amendments</u>	1
<u>Summary of Claimed Subject Matter</u>	1
<u>Grounds of Rejection to be Reviewed on Appeal</u>	2
<u>Arguments</u>	2
Office Action dated January 12, 2005	3
Office Action dated May 26, 2005	4
Final Rejection dated November 7, 2005	4
Argument over Darsillo.....	5
Argument over Darsillo in view of Bi and Alexander.....	8
Response to Examiners comments in Section 4 of the Final Office Action.....	9
<u>Summary</u>	14
<u>Conclusion</u>	14
<u>Appendix I - Claims on Appeal</u>	15
<u>Appendix II - Evidence</u>	18
<u>Appendix III – Related Proceedings</u>	19



APPELLANT'S BRIEF ON APPEAL

Appellants hereby appeal to the Board of Patent Appeals and Interferences from the Examiner's Final Rejection of claims 1, 10, 13-21, and 25 as indicated in the Advisory Action mailed February 28, 2006 (based on Final Rejection of claims 1, 3-6, 10, 12-21, and 25 which was contained in the Office Action mailed November 7, 2005).

A timely Notice of Appeal was filed March 10, 2006.

Real Party In Interest

Eastman Kodak Company is the assignee and the real party in interest.

Related Appeals And Interferences

No appeals or interferences are known which will directly affect or be directly affected by or have bearing on the Board's decision in the pending appeal.

Status Of The Claims

Claims 1, 10, 13-21 and 25 are currently pending, and are the subject of the Appeal.

Claims 2-9, 11-12 and 22-24 are cancelled.

Appendix I provides a clean, double spaced copy of the claims on appeal.

Status Of Amendments

An Amendment After Final mailed February 7, 2006 was entered in accordance with the Advisory Action mailed February 28, 2006.

Summary of Claimed Subject Matter

The invention of independent claim 1 is directed towards an image-receiving element comprising a mixture of large (page 7, line 23 to page 8, line 17) and small (page 6, line 29 to page 7, line 22) particles wherein said large and said small particles are shelled (page 5, lines 3-15) with a material providing image fade resistance selected from the group consisting of hydrolyzable organosilanes (page 6, lines 3-20), aluminasilicate polymers (page 6, lines 21-28)

and metal oxyhydroxy complexes (page 5, line 15 to page 6, line 2), and wherein said large particles and said small particles have a ratio of from 65:35 to 35:65 (page 8, line 24), wherein said small particles have a median particle size of between 80 and 140 nm (page 7, lines 4-5), wherein said large particles have a median particle size of between 200 and 300 nm (page 7, lines 29-30), wherein said image-receiving element has a porosity of greater than about 40% (page 9, lines 7-8), and wherein said image-receiving element has a 60° gloss of greater than 25 (page 9, lines 13-15). In particular, the invention relates to an image receiving element designed for inkjet use, where it has been found that this combination of properties results in an inkjet receiver that has a very good combination of rapid absorption of ink and a glossy surface and resistance to fade (page 19, lines 4-8).

Grounds of Rejection to be Reviewed on Appeal

1. Claims 1, 10, and 13-21 are rejected under 35 USC 103 over Darsillo et al. (6,365,264).
2. Claims 1, 10, 13-21, and 25 are rejected under 35 USC 103 over Darsillo et al. (6,365,264) in view of Bi et al. (2004/0197498) and Alexander et al. (3,007,878).

Arguments

Reproduced below are the first rejection of claims over Darsillo et al. under 35 USC 103 in paragraph 4 of the action of January 12, 2005. Also reproduced below is paragraph 4 of the office action of May 26, 2005 where the first rejection over Darsillo et al. (264) in view of Bi et al. (498) and Alexander (878) appear. After these paragraphs there is produced paragraph 4 of the Final Rejection which states the "reasons set forth below" referenced in the Final Rejection.

Office Action dated January 12, 2005

4. Claims 1-23 are rejected under 35 U.S.C. 103(a) as being unpatentable over Darsillo et al. (6,365,264). The reference discloses a recording medium having a glossy coating thereon with first and second groups of particles (see the abstract). The first particles may be pyrogenic silica and may be treated to make it cationic with aluminum chlorohydrate (see col. 4 line 59 to col. 5, line 10). This treatment should create an aluminosilicate shell on the particles. The ratio of the groups of particles to each other overlaps with those instantly claimed (see the abstract). The second group of particles may be colloidal silica and may be surface treated (see col. 8, line 51 to col. 9, line 9). To make the particles cationic, treatment with alumina, forming an aluminosilicate shell, would have been obvious to one of ordinary skill in the art since it is well known that alumina is cationic and will cause the surface of the silica to become cationic if so treated. The first group of particles has a primary particle size of less than about 100 nm with aggregates of from about 100 to about 500 nm. The second set of particles are less than about 50% of the mean diameter of these aggregates (see the abstract). The reference is concerned with gloss but does not measure gloss in the terms of claims 11 and 12. However, based upon the discussion of gloss in col. 3 of the reference, it would have been obvious to one of ordinary skill in the art to control and determine gloss of the medium in order to achieve desired visual results. Due to the small particle range set forth at col. 5, lines 11-42, the first group of particles would inherently meet the standard deviation values of claims 13 and 14. Furthermore, the reference suggests that both sets of particles can have diameters that are all substantially the same (see col. 6, lines 51-63 and col. 8, lines 14-28). The larger particles may be pyrogenic or fumed silica. The smaller particles may be colloidal silica. The colloidal silica set forth in Example one is spherical. Pyrogenic silica is usually formed into chains that would be of irregular shape. Therefore, these aspects would have been obvious to one of ordinary skill in the art. The medium of the reference would be inherently porous (see col. 7, lines 6-9) although the reference does not appear to set forth the porosity of the layer. Based upon the awareness of the importance of this property by the applied art, it would have been obvious to one of ordinary skill in the art to optimize the porosity of the layer in order to obtain desired ink absorption capacity.

Office Action dated May 26, 2005

4. Claims 1-25 are rejected under 35 U.S.C. 103(a) as being unpatentable over Darsillo et al. (6,365,264) for reasons of record and further in view of Bi et al. (2004/0197498) and Alexander et al. (3,007,878) for reasons given below. Bi et al. discloses treating silica particles to make them cationic for inclusion in an ink jet recording sheet [0027-0031]. The treatment may be with a hydroxyl-containing polyvalent metal salt or a cationic resin. The reference discloses that such a polyvalent metal salt with disclosed in Alexander et al. (3,007,878) and incorporates this reference. Figure 1 of Alexander et al. shows the surface of silica that has been complexed with a metal oxyhydroxy material. This complex appears consistent with applicants' claims 24 and 25. Based upon the preference of the primary reference for cationic treatment of silica, the disclosure of Bi et al. that the teachings of Alexander et al. are relevant to treat silica to render it cationic for inclusion of ink jet recording media, and the teachings of Alexander to formation of what is an aluminum oxyhydroxy complex, it would have been obvious to one of ordinary skill in the art to treat the silica of the primary reference as set forth in Bi et al. and Alexander et al. to render the silica cationic.

Final Rejection dated November 7, 2005

4. Applicant's arguments filed August 29, 2005 have been fully considered but they are not persuasive. The rejection under 35 USC 102 has been overcome. With respect to the rejection over Darsillo et al., applicants' arguments are not persuasive for the following reasons. Applicants argue that the reference does not disclose the porosity and the gloss as recited by amended claim 1. This is not persuasive because while not disclosing gloss in the terms set forth by applicants, the reference does disclose the importance of gloss and measures the 75° specular gloss in lieu of the 60° gloss recited by applicants. This is a difference in measurement technique. The reference has identified the property, its desirability, and how to measure the property. Thus it would have been obvious to one of ordinary skill in the art to optimize this property in accordance with the reference. With respect to porosity, the reference also discusses this property and the importance of this property. Measurement of the property is discussed at col. 5, line 60 to col. 6, line 22. Once again, from this disclosure, it would have been obvious to one of ordinary skill in the art to determine and control porosity of the layers in order to allow the desired degree of ink absorption. Next, applicants argue that the reference does not disclose core shell particles. Applicants argue that in order for a particle to be core shell, the surface has to be chemically modified with a distinct composition from the core. This is clearly described by the.

reference at col. 5, lines 1-10. The reference specifically uses the term "surface modification" to describe this process. The importance of properties such as porosity, gloss and fade resistance are all well known to one of ordinary skill in the art. Contrary to applicants' arguments, when the reference states that "it is sometimes preferred" it is stating a preference for cationic particles. The reference discloses both inherently cationic particles and particles that become so through surface modification with a distinct composition, i.e. core/shell particles.

With respect to image fade resistance, contrary to applicants' assertions, there is no definition in the specification that limits the term to issues of light-fastness and oxidative resistance. In addition, inclusion of cationic materials in ink receptive layers does reduce image fade. Cationic agents fix anionic dyes by adsorption making the dyes less likely to react with undesirable oxidative species. This makes the material fade resistant as well as preventing bleeding in the medium. Since applicants do not have a limiting definition of image fade in their specification, they must rely on the more generic use of the term known in the art.

The examiner has also reconsidered Table 1 in view of applicants' claim amendments. The results are not persuasive because there are too many variables changed in these showings. Not only is there a difference in whether or not the particles have a shell, but adding the shell also changes the particle diameters of both the small particles and the large particles. Changes in results cannot be attributed to the shell because two other values are varied at the same time, i.e. the size of the small particles and size of the large particles. Of course, by changing the particle sizes, the particles will be packed differently and changes in absorption and gloss can no longer be attributed to whether or not the particles have a shell. Therefore, applicants' statement that "for the inventive examples wherein the particles are shelled with a material providing image fade resistance, surprisingly, gloss increases upon introduction of larger particles, and concurrent, high-porosity, high-gloss and low-fade are achieved only over the inventive region, having a surprisingly high-fraction of large particles" has not been supported by showings. In order for the showings to demonstrate the results that applicants intend for them to demonstrate, the shelled and unshelled particles used in the examples should be the same size.

Next, applicants argue that the gloss of the reference is "poor" unless the medium is calendared. It is unclear why applicants consider the levels of gloss disclosed by the reference to be poor. Applicants claim gloss levels as low as 15, however, the reference level of 17.2 is considered by applicants to be poor. Clarification is requested concerning this argument.

Argument over Darsillo

While Darsillo et al. discloses a recording medium with two different particles, Darsillo et al. does not demonstrate the advantages of porosity,

gloss and image fade resistance as achieved by the use of the particle sizes, ratio of particles and selection of shelling material as set forth in the claims. It is respectfully urged that Darsillo et al. does not indicate a preference for cationically shelled particles but merely states that “[i]t is sometimes preferred that that cationic particles be included in glossy coating.” Furthermore, none of the examples disclosed in Darsillo et al. include surface treated, or cationically shelled particles of any kind. Examples 14-16 of the reference include pyrogenic alumina, which is a cationic particle, but it is not shelled. As discussed above there is an important distinction between a cationic particle and a shelled particle. A cationic particle is simply a particle with a positive charge. However, a shelled particle is a particle in which the surface of the particle has been chemically modified with a composition of matter that is distinctly different from that of the core, or interior of the particle. Therefore, it is respectfully urged that the particles as disclosed in Darsillo et al. are not disclosed as surface chemically modified as in the present invention. Further, the image-receiving element of Darsillo does not disclose the selected ratio of small and large particles, the median particle size of the small and large particles as selected, the 40% porosity or the 60° gloss of greater than 25.

Applicants would further like to clarify the term image fade resistance as disclosed in the instant invention. As the Examiner has correctly pointed out it is well known that cationic materials will fix anionic dyes, making them less subject to bleeding and “fading.” The proper term for this property is bleeding or water-fastness. Image fade resistance in our case is distinct in that it refers to light-fastness and oxidative resistance of the image in dry conditions. This is defined in the background of the instant invention on page 2 lines 8-10, and further on page 4 lines 23-28. The materials defined in the instant invention are selected from a unique set of materials that have been shown to provide light-fastness and oxidation resistance also known as image fade resistance.

Applicants respectfully direct the Board of Appeals to the data of Table 1. The examples C1-C7 are essentially directly comparable to those of Darsillo et al. and essentially reproduce the reference result (a trade off between porosity and gloss with no fade resistance). The instant invention demonstrates

surprising results in light of Darsillo et al. When particles of the specified size and ratio of sizes have a surface-modification providing image fade resistance are used to construct an image recording medium, highly porous and highly glossy coatings are obtained at relatively high fractions of large particles over a limited range. This is demonstrated in Table 1 of the specification at page 18.

Table 1

<u>Example</u>	<u>Percent Small Particles</u>	<u>Percent Large Particles</u>	<u>Shell</u>	<u>Percent Porosity</u>	<u>60° Gloss (%)</u>	<u>Percent Magenta Fade</u>	<u>Percent Cyan Fade</u>
C-1	100	0	None	42	40	40	11
C-2	89	11	None	45	31	48	40
C-3	77	23	None	48	29	26	50
C-4	66	34	None	52	12	28	50
C-5	55	45	None	55	6	19	47
C-6	44	56	None	60	5	17	60
C-7	32	68	None	65	9	12	54
C-8	100	0	Yes	33	4	3	0
C-9	89	11	Yes	37	7	0	0
I-1	77	23	Yes	42	16	0	6
I-2	66	34	Yes	39	29	1	18
I-3	55	45	Yes	48	29	2	15
I-4	44	56	Yes	52	33	4	25
I-5	32	68	Yes	58	31	4	11

For the comparison examples, the general trends taught in the art are observed, porosity increases and gloss decreases as the percentage of large particles increases, see C-1 through C-7. However, for the inventive examples wherein the selected size particles in the proper ratio are shelled with a material providing image fade resistance, surprisingly, gloss increases upon introduction of larger particles, and concurrent, high-porosity, high-gloss and low-fade are achieved only over the inventive region, having a surprisingly high-fraction of large particles.

In Darsillo et al. glossy coatings are obtained only after calendering the coating, see Table 3 column 17. Calendering is a method applying pressure to the coating surface to make it smoother and hence to improve gloss. Calendering

can be both expensive and time consuming. Compare the results for the comparison example 3A with that of example 3 in Darsillo et al., the gloss is poor for both, unless calendering is used, and exhibits the usual trend of improved gloss for introduction of smaller particles.

Therefore, it is respectfully urged that the present invention as amended is non-obvious since Darsillo et al. does not teach concurrently achieving high-porosity, high-gloss and image fade resistance by use of shelled particles as disclosed in the present invention as amended. Furthermore, image fade resistance would not have been an inherent property of Darsillo et al. because the reference did not teach the use of the image fade resistant materials as claimed in the instant invention applied to particles of a selected size and size ratio. Therefore, it is respectfully requested that this rejection be reconsidered and withdrawn.

Argument over Darsillo in view of Bi and Alexander

The Examiner has rejected claims 1, 3-6, 12-21 and 25 under 35 U.S.C. § 103 as being unpatentable over Darsillo et al. in view of Bi et al. (2004/0197498) and further in view of Alexander et al. (3,007,878). The Examiner indicates that Bi et al. discloses treating silica particles to make them cationic for inclusion in an ink jet recording sheet. The Examiner further indicates that Alexander et al. discloses the surface of silica that is complexed with a metal oxyhydroxy material. The Examiner states that it would have been obvious to one of ordinary skill in the art to treat the silica of Darsillo et al. as set forth in Bi et al. and Alexander et al. to render the silica cationic. This rejection is respectfully traversed.

As discussed above Darsillo et al. discloses a recording medium with two different particles, however, fails to teach particles, such as specified in the claims, shelled with hydrolyzable organosilanes, aluminasilicate polymers or metal oxyhydroxy complexes, and further fails to teach porosity and gloss and particle size and particle ratio as claimed in the present invention. Bi et al discloses a two-layer coating in which each layer is composed of cationic silica, but fails to teach shelled particles as disclosed in the present invention. Alexander

et al. discloses coating the surface of silica with an oxygen compound of a polyvalent metal added as basic salt. However, none of these references alone or in combination teach or suggest an image-receiving element containing two different sized particles of specific size and ratio, shelled with hydrolyzable organosilanes, aluminasilicate polymers or metal oxyhydroxy complexes, and wherein the element has both porosity and gloss as claimed in the present invention. Therefore, it is respectfully requested that this rejection be reconsidered and withdrawn.

Response to Examiners comments in Section 4 of the Final Office Action.

On page 2 of the Final Office Action, the Examiner states that the Applicant's arguments concerning gloss are not persuasive as the measurement of gloss at 75 degrees instead of the applicants' 60 degrees is a matter of measurement technique and that it would be obvious to one of ordinary skill to optimize the property. It is respectfully urged that there is a significant difference between gloss measurements at 60 degrees and 75 degrees. The appellant has provided two publications discussing gloss measurement. These publications are "The Measurement of Gloss" by A. H. Pfund (article dated October 1929, published as pages 23-26 of J.O.S.A., 20 Jan., 1930), and "Gloss as an Aspect of the Measurement of Appearance" by Wei Ji et al., J. Opt. Soc. Am. January 2006 Vol. 23, No. 1, pp. 22-33). These publications were originally provided with Applicant's Amendment After Final mailed February 7, 2006 (as evidenced by the Electronic File Wrapper for the instant application, wherein a copy of such documents have been entered into the Electronic File as a 16 page document with the title "Applicant Arguments/Remarks Made in an Amendment" with a Mail Room date of February 10, 2006). The Board of Appeal's attention is directed to page 24 of Pfund for a discussion of how the measurement is done and to page 23 of Ji et al for a discussion regarding Figure 1 where it is shown how 60 degree gloss and 75 degree gloss measurements differ for a semi-glossy article. It is noted that the appellant has raised the gloss limit of claim 1 to be even further from the range of Darsillo et al. It is urged that while gloss was known in the art,

it was not obvious from the art to create the claimed article by selection of materials and characteristics as instantly disclosed and claimed.

At the top of page 3 of the Final Office Action, the Examiner states that it would be obvious to control the porosity as claimed. However the appellants' porosity is not shown or suggested by the reference. The Darsillo reference, at col. 5 and 6 as pointed out by the Examiner, discloses porosity of the particles and not the layer of the image-receiving member. In any case, the applicants' invention is directed to the formation of a sheet with a good balance of stability, gloss, and porosity by selection of particular particle size, size ratio, and shell material. The knowledge that such properties existed does not make obvious the invention article as there is no teaching to suggest or disclose an article as now claimed.

At page 4, the Examiner states that the Examples are not convincing as the size change after shelling would affect the results such that the difference in size before and after shelling means that the comparisons are not convincing. However it is urged that the shell is so thin that the particle size after shelling is substantially the same as before shelling. The Examiner's attention is directed to the description of the shelled particles in the Examples themselves as described at pages 13 and 14 of the instant specification, where the shell is shown to be less than 10% of the diameter. As the shelled particles are necessarily prepared from the comparison unshelled particles, it would be a hardship to find and prepare shelled and unshelled particles having exactly the same particle size. It is respectfully urged that this small size difference in particle size between the shelled and unshelled particles is not enough to make the Examples not convincing, especially in light of the difference in size of the large and small particles themselves which are employed in the Examples (which is approximately 100% of the diameter of the small particles), which accordingly will have a much greater impact on porosity in accordance with the requirements of the invention. As Applicants have provided evidence of the surprising effects of the present invention, with reasonably explanation as to why such evidence is appropriate for demonstration of the inventive effect even though the comparison particles may not be exactly the same size as the inventive example particles, it is submitted that

it is accordingly unfair and inappropriate to require Applicants to go to the expense of generating such additional examples based on an unsupported allegation that such minor difference in shelled/unshelled particle size would substantially impact the experimental results.

In the paragraph at the bottom of page 4 of the Final Office Action, the Examiner states that it is unclear why the applicants consider the levels of gloss of the reference to be poor. The Examiner points out that the reference has gloss of 17 while the Applicant has gloss as low as 15. As discussed above, the 75 degree gloss of 17 would be less than the 60 degree gloss of 15 if measured at 60 degrees. Nevertheless, the Appellant has now limited the claims to 60 degree gloss of greater than 25, which is not anywhere close to the gloss in the reference. Darsillo must calendar to obtain that high a gloss, whereas the instant claimed invention allows formation of an image-receiving layer with higher gloss than the prior art material.

Darsillo et al. discloses a recording medium with two different particles, however. Darsillo et al. does not demonstrate the advantages of porosity, gloss and image fade resistance as achieved by the use of the particle sizes, ratio of particles and selection of shelling material as set forth in the claims. It is respectfully urged that Darsillo et al. does not indicate a reasoned preference for cationically shelled particles but merely states that “[i]t is sometimes preferred that that cationic particles be included in glossy coating.” Furthermore, none of the examples disclosed in Darsillo et al. include surface treated, or cationically shelled particles of any kind. Examples 14-16 of the reference include pyrogenic alumina, which is a cationic particle, but it is not shelled. As discussed above there is an important distinction between a cationic particle and a shelled particle. A cationic particle is simply a particle with a positive charge. However, a shelled particle is a particle in which the surface of the particle has been chemically modified with a composition of matter that is distinctly different from that of the core, or interior of the particle. Therefore, it is respectfully urged that the particles as disclosed in Darsillo et al. have not been chemically modified as in the present invention.

In response to the Amendment After Final of February 28, 2006, the Examiner states as follows:

The request for reconsideration has been considered but does NOT place the application in condition for allowance because: the rejections of record are still considered to be proper. Some of the reasons why the rejections are still proper are given in the final rejection. With respect to image fade, there is no discussion in the specification of this being related or only relevant to dry conditions. The specification teaches that image fade is prevented by a material that provides resistance to oxidation and light. The materials at the top of col. 5 of the reference fulfill this function and fit within broad groups recited by claim 1. Applicant's comparative examples are not representative of the closest examples of the reference. These would be the examples employing cationic particles. It would have been expected that the image fade results are improved through use of cationically charged particles, whether the charge is provided by a cationic shell or a solid particle. There is nothing to support that improvement in results due to the core shell nature of the particles rather than the cationic nature of the particles. With respect to gloss and porosity, the recognition in the prior art of these properties and of how to control the properties would have made their optimization obvious to one of ordinary skill in the art. Applicants allege that the gloss values of the reference are different than those instantly claimed, but do not demonstrate this to be true. The examiner is aware that the reference measures gloss differently than do applicants, but it would have been obvious to one of ordinary skill in the art to optimize the property of gloss based on the disclosure of the reference. Finally, applicants allege, but have not demonstrated, that less than a 10% size difference attributed to the shell would have little or no impact on results. To overcome the lack of constancy of the particle sizes in their examples, applicants would have to demonstrate what they have only alleged, i.e. that the change in particle size due to the shell is not significant enough to impact properties of gloss, porosity and image fade.

In response to the Amendment After Final, the Examiner has again stated that the examples are not convincing as to an advantage set forth by each of the limitations of the claim. However, it is respectfully urged that further proof is not necessary in this application as a prima facie rejection has not been made. Claim 1 sets forth the following 7 differences between the references to Darsillo et al. and the other art. These differences are selections from broader ranges suggested in the art or entirely new limitations not considered in the art.

1. The large and small particles are shelled.
2. The shell material is selected from hydrolyzable organosilanes, aluminasilicate polymers and metal oxyhydroxy complexes.
3. The large and small particles have a ratio of between 65:35 to 35:65.
4. The small particles have a medium-sized of between 80 and 140 nm.
5. Large particles have a median particle size of between 200 and 300 nm.
6. The image-receiving element has a porosity of greater than about 40%.
7. The image-receiving element has a 60° gloss of greater than 25

The Examiner has provided no teaching or suggestion in the art to select the limited ranges of any one item as set forth above much less a teaching or suggestion to make an image receiving element that has all these 7 limitations. By the selections to form the element as claimed an element of high-gloss (without calendaring) and high absorption is obtained. A comparison with any one of these limitations and the art would not be significant or dispositive of the obviousness and patentability invention as the combination of features of the claimed image-receiving element is the invention. The entirety of the invention must be examined not independent pieces. The Examiner must show teachings that the entire invention as claimed is obvious. Even if the selection of one or two features independently is obvious does not make the whole claim1 obvious, unless a teaching to make the entire claim obvious is found by the Examiner. As pointed out, the appellant's Examples are convincing as to the gloss and absorption properties of the claimed element. These properties are not present in the example comparisons and have not been demonstrated by the Examiner as disclosed or suggested in any combination of the cited art. Even less has it been shown that the properties are reached by the applicant's claimed seven feature invention. It is respectfully urged that the Examiner wishes to examine each element of the claim separately rather than the entire claim 1 which is the claimed invention. The invention has been narrowly claimed to result in a preferred element not disclosed or suggested by the art. Therefore, it is respectfully requested that the rejections be reversed.

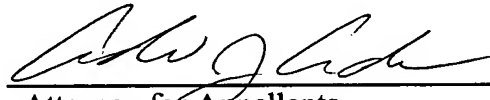
Summary

It is respectfully requested that the rejections be reversed as there is no teaching of suggestion in the art that makes obvious the entire article as claimed. The Examiner has set forth no suggestions that would lead one to the claimed invention with seven features never combined, prior to this invention, to reach an improved image-receiving article.

Conclusion

For the above reasons, Appellants respectfully request that the Board of Patent Appeals and Interferences reverse the rejection by the Examiner and mandate the allowance of claims 1, 10, 13-21, and 25.

Respectfully submitted,



Attorney for Appellants
Registration No. 33,564

Andrew J. Anderson/vjr
Telephone: 585-722-9662
Facsimile: 585-477-1148
Enclosures

If the Examiner is unable to reach the Applicant(s) Attorney at the telephone number provided, the Examiner is requested to communicate with Eastman Kodak Company Patent Operations at (585) 477-4656.

Appendix I - Claims on Appeal

1. An image-receiving element comprising a mixture of large and small particles wherein said large and said small particles are shelled with a material providing image fade resistance selected from the group consisting of hydrolyzable organosilanes, aluminasilicate polymers and metal oxyhydroxy complexes, and wherein said large particles and said small particles have a ratio of from 65:35 to 35:65, wherein said small particles have a median particle size of between 80 and 140 nm, wherein said large particles have a median particle size of between 200 and 300 nm, wherein said image-receiving element has a porosity of greater than about 40%, and wherein said image-receiving element has a 60° gloss of greater than 25.

10. The image-receiving element of claim 1 wherein said element has a porosity from about 50 to 70%.

13. The image-receiving element of claim 1 wherein said small particles have a particle size distribution with a standard deviation of less than 50 nm.

14. The image-receiving element of claim 1 wherein said small particles have a particle size distribution with a standard deviation of between 1 and 25 nm.

15. The image-receiving element of claim 1 wherein said large particles have a particle size distribution with a standard deviation of less than 150 nm.

16. The image-receiving element of claim 1 wherein said large particles have a particle size distribution with a standard deviation of between 10 and 100 nm.

17. The image-receiving element of claim 1 wherein said large particles comprise fumed silica.

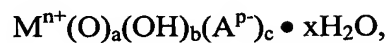
18. The image-receiving element of claim 1 wherein said large particles have an irregular shape.

19. The image-receiving element of claim 1 wherein said small particles comprise colloidal silica.

20. The image-receiving element of claim 1 wherein said small particles are generally spherical.

21. The image-receiving element of claim 1 wherein said small particles are generally symmetrical.

25. The image-receiving material of claim 1 wherein said metal oxyhydroxy complexes comprise



wherein

M is at least one metal ion;

n is 3 or 4;

A is an organic or inorganic ion;

p is 1, 2 or 3; and

x is equal to or greater than 0;

with the proviso that when n is 3, then a, b and c each comprise a rational number as follows: $0 < a < 1.5$; $0 < b < 3$; and $0 \leq pc < 3$, so that the charge of the M^{3+} metal ion is balanced;

and when n is 4, then a, b and c each comprise a rational number as follows: $0 < a < 2$; $0 < b < 4$; and $0 \leq pc < 4$, so that the charge of the M^{4+} metal ion is balanced.

Appendix II - Evidence

“The Measurement of Gloss” by A. H. Pfund (article dated October 1929, published as pages 23-26 of J.O.S.A., 20 Jan., 1930)

“Gloss as an Aspect of the Measurement of Appearance” by Wei Ji et al., J. Opt. Soc. Am. January 2006 Vol. 23, No. 1, pp. 22-33).

Statement setting forth where in the record the evidence was entered by the

Examiner:

These publications were originally provided with Applicant’s Amendment After Final mailed February 7, 2006 (as evidenced by the Electronic File Wrapper for the instant application, wherein a copy of such documents has been entered into the Electronic File as a 16 page document with the title “Applicant Arguments/Remarks Made in an Amendment” with a Mail Room date of February 10, 2006), prior to the filing of a Notice of Appeal, and referenced in the associated arguments against and request for reconsideration of the final rejection. The Advisory Action mailed February 28, 2006 states that the Amendment After Final will be entered, and that the request for reconsideration has been considered. Accordingly, such Advisory Action constitutes evidence that such publications have been accepted into the record by the Examiner.

None

Appendix III – Related Proceedings

THE MEASUREMENT OF GLOSS

By A. H. PFUND

SUMMARY

It is proposed to measure the specular-reflection from various materials and to determine objective gloss which defines surface characteristics only. Samples are mounted on a circular cylinder which is spun rapidly. Large angles of incidence are employed. The brightness of the image of a source reflected specularly from the cylindrical sample is photometered by means of an optical pyrometer. Actual results show that gloss so measured is independent of the brightness of the back-ground (diffuse reflection).

When light falls on materials such as enamel, silk, paper etc., specular as well as diffuse reflection takes place. The smoother the surface, the greater is the intensity of the specularly reflected light and the greater, hence, is the lustre or gloss. It is recognized that if two materials, one white and the other black, have the same surface characteristics, the black one will *appear* the glossier. From this statement it is evident that gloss may be defined in two ways: first, according to the sensation of glossiness (subjective) or, secondly, according to the actual surface condition (objective). Subjective gloss is defined¹ as the ratio of the specular to the diffuse reflection. Obviously, if a black and a white material were given the same subjective gloss, the surface characteristics would be violently different. Now, the manufacturers of varnish, paper, fabric, etc., are interested primarily in the surface itself—regardless of the nature of underlying color. In other words, they are interested in producing materials of definite finish regardless of whether the background be green, red or blue. In the following, this problem is attacked by formulating a definition of objective gloss and by describing an instrument which measures the desired quantity.

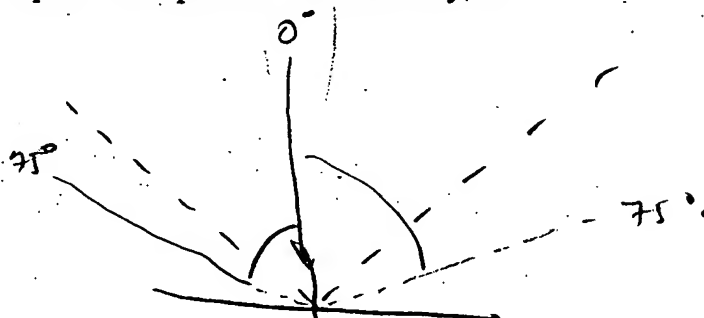
Objective gloss is here defined as the ratio of the intensity of light reflected specularly from the material in question, at a stated angle of incidence, to the intensity of light reflected specularly from a perfectly polished surface of the same material, at the same angle of incidence.

To measure the specular reflection only, it is necessary to suppress the diffuse reflection. This is accomplished by giving to the test-object a cylindrical form and by resorting to large angles of incidence. Because of the cylindrical form, a virtual image of the light-source is formed. For a perfect reflector, and to a greater or lesser extent, for partial reflectors, the intrinsic luminosity of the image of a finite source does not vary as the distance from the source is increased. Consequently, it is

¹ L. A. Jones, J.O.S.A., & R.S.I., 6, p. 147; 1922.

possible to remove the source to such a distance that the diffusely reflected light becomes negligible in comparison with the intrinsic luminosity of the image formed by specular reflection. Again, by increasing the angle of incidence, the diffuse reflection decreases while the specular increases. Experience has shown that at an angle of incidence (and of reflection) of 75° or thereabouts, the diffuse reflection has been removed to all intents and purposes for all but the least glossy surfaces. For surfaces having very high gloss it has been found best to use nearly normal incidence (5°) while for surfaces which are very matte, grazing incidence (85° or more) has been found to yield sharpest discrimination. Considering the wide variety of materials whose gloss is to be measured, it is obviously out of the question to find a perfect reflector for each substance. It is to be noted, however, that paper, fabric, paints, etc., have approximately the same refractive index as glass. Therefore, a cylinder of soda glass blackened on the inner surface, and having a high optical polish, was chosen as the standard. Incidentally it may be mentioned that the cylindrical form given the sample holder has the great advantage of making it easy to give a regular geometrical form to the sample. To prepare a surface that is sufficiently plane for reflection measurements is at times difficult. Anticipating the results to be presented it may be said that the entire range of objective gloss—extending from that of polished glass to that of surfaces fumed with MgO or soot may be covered.

The essentials of the gloss-meter are shown in Fig. 1. Here A is a substantial vertical post bearing a fixed pivot, D , and a movable collar, E . Attached to these is an adjustable parallelogram $B B' C C'$ pivoted at all corners. Illumination of the cylindrical sample H is effected by an incandescent lamp with frosted bulb F . The pivot D is on the same level with the highest portion of the cylindrical sample so that, if the angle of incidence be changed by moving E , the beam reflected specularly from the sample will always lie in the direction of the arm C . The sample-holder consists of a highly polished brass sleeve H which is slid on the solid cylinder G . The latter is contiguous with a shaft mounted in a long bearing I . By means of a small motor and pulley (not shown) the sample is rotated so rapidly that all surface irregularities of the sample are wiped out. If paper or fabric is to be tested, the sample is simply wound around H —the free edge being either glued down with library paste or held down with rubber bands applied at the extremities of the cylinder. Threads of silk, rayon etc. are wound around the cylinder to form a "spool" while paints or varnishes may be



applied to the cylinder directly or better, to a sheet of thin aluminum which is wrapped subsequently about the cylinder. To measure the intrinsic luminosity of the image of *F* formed by reflection from the cylindrical surface, a small optical pyrometer *K*, supplied with a red filter *R*, is used. The specular image is of elongated form and is brightest in the middle. By adjusting the position of the pyrometer-lamp filament so that it crosses the specular image transversely it is possible to bring about the disappearance of the filament in the brightest portion of the image. Readings are taken on the milliammeter connected in series with the pyrometer lamp, battery and rheostat.

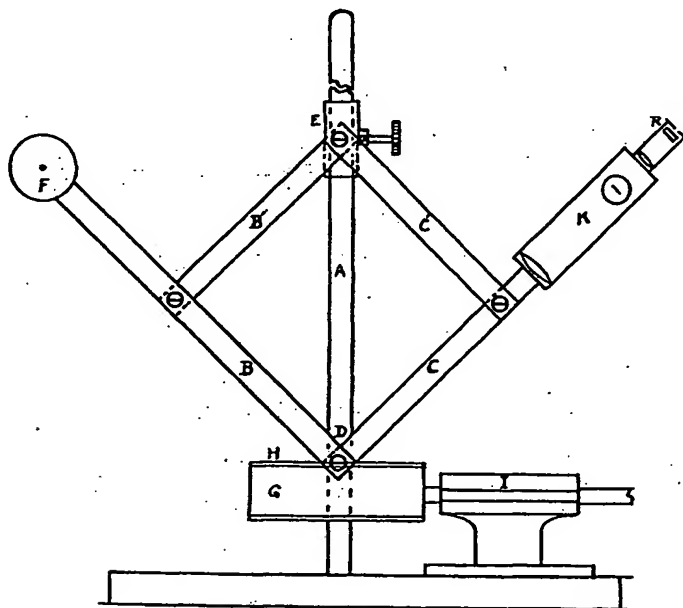


FIG. 1. Sketch of gloss-meter.

Calibration of the instrument is effected by mounting the glass standard in position and by bringing about a match in the optical pyrometer. After recording the milliammeter reading, a rotating sector of variable aperture or, a series of neutral tint screens are introduced so as to reduce the intensity of the reflected beam in known ratios. Relative light intensities are finally plotted against milliammeter readings.

The performance of the glossmeter is illustrated by the results shown in the following table. To test the degree of immunity from diffuse

reflection, samples of developing paper were tried out. Each sheet was exposed over half of its area and was then developed. In this manner, identical surface conditions with respective black and white backgrounds were realized.

Material	Gloss	Remarks
1. Glass	1.00	Standard—All angles of incidence 75%
2. This journal J.O.S.A. (print)	0.18	
3. This journal J.O.S.A. (cover 1929)	0.047	
4. Phys. Rev. print	0.07	
5. Bromide paper (black)	0.20	Same finish on both samples
Bromide paper (white)	0.20	
6. News print	0.057	Same finish on both samples
7. Black Duco	0.17	
8. Glossy Velox (black)	0.78	
Glossy Velox (white)	0.78	

While the absolute values here presented are of no particular importance, it is shown however that a wide range of gloss may be covered and, what is perhaps most important, that the value of gloss is determined solely by the surface characteristics and is uninfluenced by the brightness of the background.

JOHNS HOPKINS UNIVERSITY,
BALTIMORE, MARYLAND.
OCTOBER, 1929.

Gloss as an aspect of the measurement of appearance

Wei Ji

Department of Colour and Polymer Chemistry, University of Leeds, Leeds, LS2 9JT, United Kingdom

Mike R. Pointer

National Physical Laboratory, Hampton Road, Teddington, TW11 0LW, United Kingdom

Ronnier M. Luo

Department of Colour and Polymer Chemistry, University of Leeds, Leeds, LS2 9JT, United Kingdom

John Dakin

DigiEye PLC, Quartz Close, Warrens Business Park, Enderby, Leicester, LE19 4SG, United Kingdom

Received January 21, 2005; revised manuscript received April 21, 2005; accepted June 3, 2005

The perception and measurement of gloss is just one part of the concept of appearance measurement. We describe the comparison between data derived by 20 observers who each scaled the perceived gloss of a set of 84 neutral and colored test samples and measurements of those samples made using a glossmeter and a sphere-based spectrophotometer. With a glossmeter, the relationship between the visual-scaled data and the measured gloss values could be described by a three-part linear fit or, with a higher correlation, a cubic function. For the sphere-based spectrophotometer, the difference in the luminance factor, ΔY , between specular-included and specular-excluded measurements, was found to give a better linear correlation with the observer-scaled data. The color of the samples did not appear to significantly change the perceived gloss of the surface. © 2006 Optical Society of America

OCIS codes: 120.0120, 120.5700, 330.5510, 330.1690.

1. INTRODUCTION

Appearance can be described in terms of the ability of an observer to recognize an object, and this recognition is possible because of the interaction between light and the material of the object. The four major things that can happen to light when it encounters an object are

- Specular reflection at the first surface of the object—associated with gloss;
- Absorption within the object—largely responsible for color;
- Scattering within the object—associated with diffuse reflection and transmission: translucency and haze;
- Transmission through the object—associated with transparency, opacity, and clarity.

It has been suggested that the characterization of these optical properties of materials can be divided into at least four groups: color, gloss, translucency, and surface texture.¹ These groups are perhaps not definitive, but they represent useful categories for measurement, especially in view of the fact that measurement techniques already exist for some of them.

Currently, a glossmeter relies on a scale defined according to a physical principle.² It is important that the associated psychophysical scale derived from visual data

should correlate with the physical scale, but anecdotal evidence has suggested that this may not be the case.

Previous studies²⁻⁴ have been based on the use of neutral-colored samples and the gloss parameter quantified by the use of specialized instruments such as a goniospectrophotometer or a glossmeter. These instruments can measure only one spot on an object at a time and usually assume a fixed illumination and viewing geometry. This is not the same as human visual perception, where the whole object is viewed.

This study will investigate the relationship between the measured gloss of each set of samples and the corresponding perceived value of gloss obtained by a scaling method using a group of observers. The instruments include both a conventional glossmeter and a sphere-based spectrophotometer, and the samples are both neutral and colored.

2. GLOSS

Gloss is the attribute of a surface that causes it to have a shiny or lustrous, metallic appearance and is generally associated with the specular reflection of light from the surface of the object.³ The amount of this specular reflection can vary from one surface to another depending on several physical parameters:

- The fraction of light reflected in the specular direction.
- The nature and extent of the light that is spread to either side of the specular direction.
- The change in specular reflection as the specular angle changes.

Hunter was one of the first to be aware of these variations in specular reflection, and he designed, in 1934, a glossmeter to compare the capabilities of materials to reflect light at 45° to the surface normal.² He studied many different materials and concluded that there were six visual criteria that could be used to rank, and potentially to measure, their gloss:

- Specular gloss—the ratio of the light reflected from a surface at a specified angle to that incident on the surface at the same angle on the opposite side of the surface normal;
- Sheen—the gloss at grazing angles of incidence and viewing;
- Contrast gloss or luster—the ratio of the specularly reflected light to that diffusely reflected normal to the surface;
- Absence of bloom—a measure of the absence of haze or the milky appearance adjacent to the specularly reflected light;
- Distinctness of image—the sharpness of the specularly reflected light;
- Surface uniformity—a measure of the freedom from surface nonuniformities such as texture.

Thus, a surface can appear very shiny if it has a well-defined specular reflectance at the specular angle. The perception of an image reflected in the surface can be degraded by appearing unsharp or by appearing to be of low contrast. The former is characterized by the distinctness of image, and the latter is characterized by the haze or contrast gloss (haze is the inverse of absence of bloom). An added complexity is due to surface nonuniformity leading to an effect known as orange peel. This effect can be caused, for example, by uneven coating of the acrylic overcoat on an automobile finish, leading to a relatively low-frequency ripple.

3. GLOSS MEASUREMENT

As mentioned earlier, the measurement of gloss is based around a physical concept, and the gloss unit is defined such that a glass material of refractive index, n , equal to 1.567 is given a value of 100 GU for any angle of incident light.²

Many developments of gloss measurement have been carried out as part of the technical work of the American Society for Testing and Materials (ASTM), commencing in 1925 with an instrument constructed by Pfund.⁴ This instrument used parallel light to illuminate the sample at 20° with a detector placed at 20° on the opposite side of the normal. Hunter and Judd later incorporated this design into an ASTM standard method⁵ that designated three angles (20°, 60°, and 85°) for measurement, depending on the relative gloss of the surface, and measurements are made relative to the black glass standard.

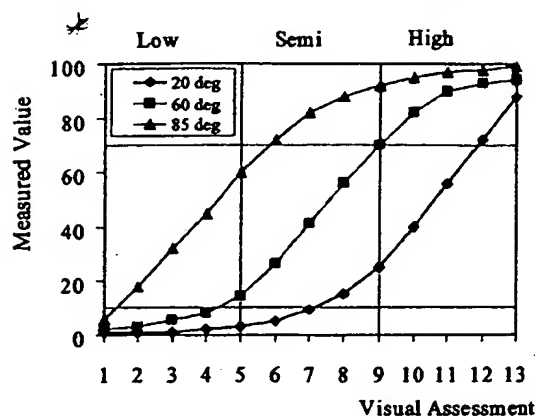


Fig. 1. Measurements of a series of samples, at three angles of illumination, as a function of the rank order of a visual assessment of their gloss.

In order to differentiate the gloss of different samples, it is necessary to select the appropriate measuring geometry. The sample is first measured with 60° geometry. If the gloss value is higher than 70 (high gloss), then it is remeasured at 20°, and, if the gloss value is less than 10 (low gloss), it is remeasured at 85°. These values were loosely defined following some experimental work described by Byk-Gardner^{3,6} in which 13 black glass tiles were visually ranked from matt to high gloss and the results compared with measurements at the three angles; see Fig. 1. It was found that the largest difference could be detected by using 85° for low-gloss samples, 60° for semigloss samples, and 20° for high-gloss samples. This appears to be the background to the recommendation that high-gloss, medium gloss, and low-gloss samples should be measured at 20°, 60°, and 85°, respectively.

Standardization in gloss measurement was led by Hunter and ASTM, who first produced ASTM D523 "Standard test method for specular gloss" in 1939. This standard incorporated a method for measuring gloss at a specular angle of 60°. Later editions of the standard (from 1951) included methods for measuring at 20° (high gloss) and 85° (matt, or low, gloss).

A number of instruments are commercially available that conform to the above standard in terms of their measurement geometry, and the standard sets tolerances for the various angles involved.

4. PREVIOUS EXPERIMENTS

The above sections of this paper discuss the establishment of the measurements of gloss and the physical principles on which these measurements are based. Harrison and Poulter,⁷ after extensive studies in which the ability of individual observers to rank a range of surfaces according to their gloss was compared with instrumental measurements, have concluded that the gloss of surfaces is not a simple physical property but a psychological gestalt, that is, an appraisal of the physical situation taken as a whole. It was found that observers tend to fall into one of two categories. In the first, observers judge gloss with reference to the total amount of light reflected from a surface, and the others judge gloss according to the sharpness of images seen via the reflecting surface.

A major comprehensive study of visual gloss scaling was made by Billmeyer and O'Donnell.⁸ Painted panels were prepared with a wide range of gloss and three achromatic colors (white, gray, and black) by varying the composition and heat treatment of an automobile acrylic lacquer system. Magnitude scaling was used to estimate the visual dissimilarities between members of all possible pairs of specimens in series of 15–20 samples. The data were analyzed using multidimensional scaling techniques. Measurements were also made using a conventional three-angle glossmeter (described below). It was considered conceivable that observers would be able to distinguish at least three types of gloss simultaneously: distinctness-of-image gloss, specular gloss, and reflection haze. The results of the multidimensional scaling analysis, however, showed that observers could not reliably distinguish more than one dimension. This perhaps suggests that there is an inherent property of a surface, related to its gloss, that was scaled by the observers and that is independent of illumination and viewing angle. Put another way, the concepts of distinctness-of-image gloss, specular gloss, and reflection haze are essentially all aspects of the same phenomenon.⁹ It was also noted that the visual data obtained in this experiment did not always correlate well with associated measurements made using the conventional glossmeter.

Another experiment that should be mentioned is that which describes a model of surface reflectance used in computer modeling and computer design software in order that the shading of objects on the CRT display matches that of the real-world objects that they are trying to mimic. This aspect of a computer-displayed image is important because the perceived shape of an object is heavily influenced by the variation (and uniformity) of the light reflected from its surface. Ferwerda *et al.*¹⁰ generated a number of computer images of white, gray, and black spheres using a model of surface reflection.¹¹ The model allowed the diffuse reflectance, the energy in the specular component, and the spread of the specular component to be varied, thus making it possible to produce a systematic array of spheres. The observers were shown pairs of spheres (378 pairs in total) and asked to judge

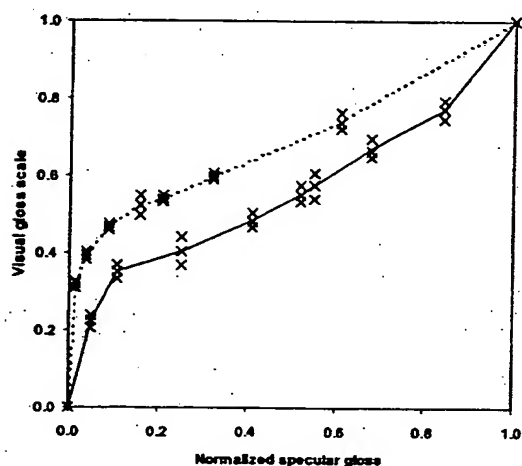


Fig. 2. Visual scales measured by one observer as a function of normalized specular gloss measured using 60° (solid curve) and 20° (dashed curve) geometry. From Obein *et al.*¹⁵

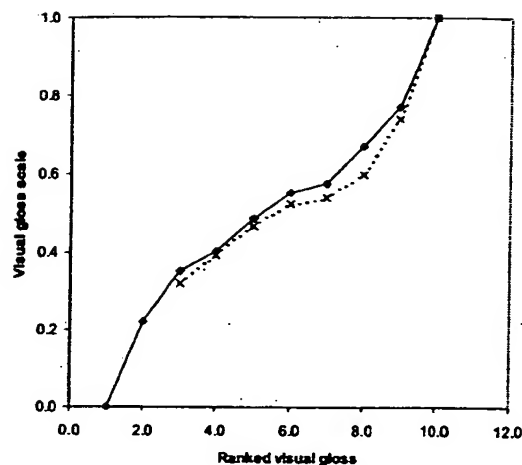


Fig. 3. Visual scales measured by one observer as a function of ranked sample number of the series. From Obein *et al.*¹⁵

their difference in terms of apparent gloss. Multidimensional scaling analysis was then applied; two dimensions were found to adequately describe the data, and these could be related to the apparent contrast of the reflected image (contrast gloss) and the distinctness of the reflected image (distinctness of image). A second experiment was conducted to place metrics on these two axes. Observers were asked to use magnitude estimation to scale the perceptual gloss dimensions, using a subset of the spheres from the first experiment. Analyzing these data showed that the perceived gloss values enabled the derivation of a model that relates the perceived contrast gloss and distinctness-of-image gloss to parameters of a model used to display correctly shaded images on a computer display.¹²

Obein *et al.*^{13–15} argue that gloss is very much a second-order visual attribute in that it results from an interpretation by the brain of first-order signals. This implies that an observer must look at an object from two or three different angles to receive enough information to be able to attribute a value to the gloss of that surface. Their work showed that the scaled visual gloss of a set of samples, obtained using a pair-comparison technique, was not linearly related to the corresponding values obtained from a glossmeter; see Fig. 2. For matt samples, the visual scale undergoes compression, and, for very-high-gloss samples, the gain of the visual responses rises steeply. In the intermediate range, the two scales are almost linearly related. They show that this agrees with the work of Ferwada *et al.*¹⁰ and Harrison and Poulter.¹⁶ This concept also has some similarities with the findings of Billmeyer and O'Donnell.⁸ Analysis of the Obein *et al.* data also shows that the observers exhibit a form of gloss constancy. When data obtained using two observing angles (60° and 20°) are plotted versus a unique abscissa, for example, the sample number in the series, the two plots superimpose; see Fig. 3. This would indicate that, although the flux that is collected by the eye varies according to the angle of view, an observer is able to recover a visual gloss index that is inherent to the surface. Thus, just as an observer can assign a color to a sample under lights of different spectral power distributions, he can also assign a gloss

value to a surface despite the change in geometrical distribution of the light, a finding first discussed by Billmeyer and O'Donnell.⁸

5. NEW VISUAL EXPERIMENTS

A. Samples

An experiment was designed in which a number of observers would visually scale the apparent gloss of a series of samples as seen in defined viewing conditions. A set of samples was prepared that consisted of 84 neutral and colored patches. The Swedish Colour Foundation, the manufacturer of the Natural Color System (NCS), kindly donated three neutral gloss scales (white, gray, and black), each with samples at six levels of gloss, and eight NCS colors, each at two levels of gloss. Thus, chromatic group I consisted of 16 samples: eight NCS colors at two levels of gloss (about 90 and 17 GU, respectively, measured using a glossmeter with illumination and viewing at 60°). Chromatic group II consisted of an additional 11 NCS colored samples. These were chosen such that they filled in the gaps in color space between the samples in chromatic group I. They were each available at only one, high level of gloss. Two additional levels of gloss samples were produced by hand spraying a gloss-coating agent onto duplicate samples of some of the colored matt samples and hand spraying a matt-coating agent onto duplicate samples of some of the colored gloss samples. The

two spray coating agents used were 101 Gloss Coating and 103 Matt Coating for Artwork manufactured by Es-selte Letraset Limited.

A black-pile sample having a measured gloss value of less than 1 GU (0.2 GU measured by the Sheen 160/T at 60°) was also included.

In total, 84 samples were available for use, and the subsets are outlined in Table 1. The spectral reflectance factor of each of these samples was measured using a GretagMacbeth CE7000A sphere-based spectrophotometer (see later). CIELAB colorimetric coordinates were calculated by the instrument software using CIE standard illuminant D65 and the CIE 1964 standard colorimetric observer. The distribution of the samples in a color sense is shown in Fig. 4(a) in a CIELAB a^*b^* diagram and Fig. 4(b) in a CIELAB L^*C^* diagram. It can be seen that the 18 neutral samples fall close to the neutral point (the intersection of the a^* and the b^* axes), and there is a reasonable distribution of colored samples covering a large range of both chroma and lightness.

Each sample was visually examined to ensure that the sprayed coating, and hence the gloss appearance, was uniform over a reasonable area of the surface of each sample. If a sample failed the visual examination, it was resprayed on a new duplicate sample until the uniformity of that sample was acceptable.

The samples were cut to be 3 in. square (7.6 cm by 7.6 cm) and mounted on cards with one extended edge to facilitate handling; see Fig. 5. The thickness of the card was 2 mm to help ensure that the samples remained flat for the duration of the experiment. The color of the card did not affect the appearance of the sample because each gloss sample was opaque.

Table 1. Subsets of the Set of 84 Test Samples

Sample Group	Number of Colors	Gloss Levels for Each Color	Number of Samples
Neutral	3	6	18
Black pile	1	1	1
Chromatic group I	8	2	16
Chromatic group II	11	1	11
Hand-sprayed cards	19	2	38
Total	—	—	84

B. Psychophysical Experiment

The psychophysical experiment was conducted using a Macbeth SpectraLight II viewing cabinet containing illumination that simulated CIE standard illuminant D65, and the samples were assessed against a gray background with a value of CIELAB lightness, L^* , of 70.

In the experiment, observers were given a neutral (gray) reference gloss sample that they were told to assign

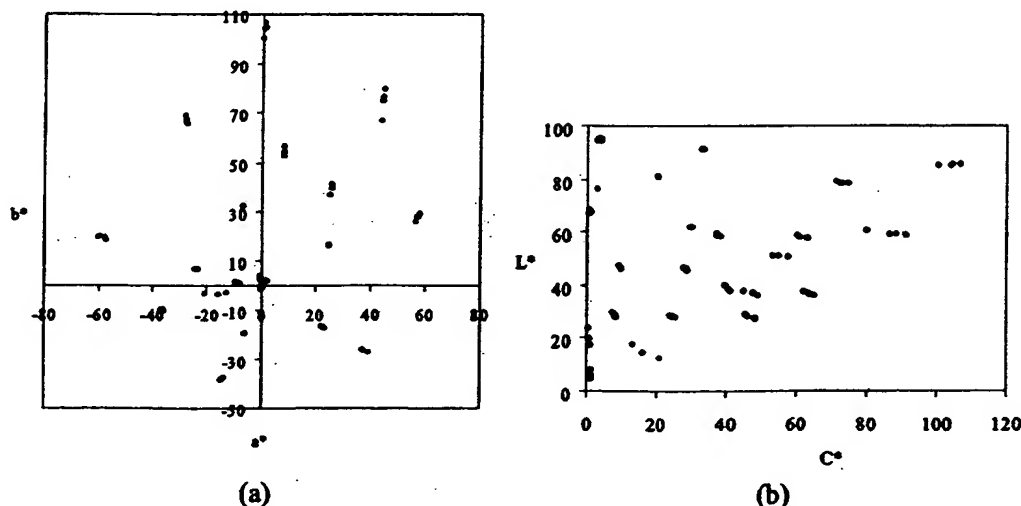


Fig. 4. Distribution of the 84 samples in (a) a CIELAB a^*b^* plane and (b) a CIELAB L^*C^* plane.

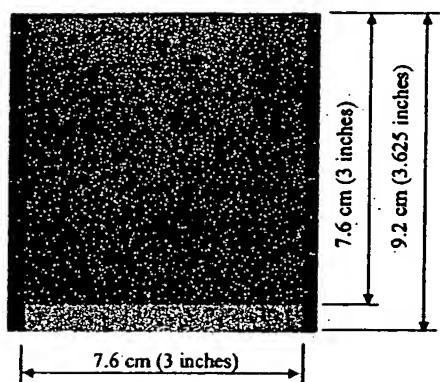


Fig. 5. Physical size of each sample after it was mounted on a card (the background of the image was a checked board).

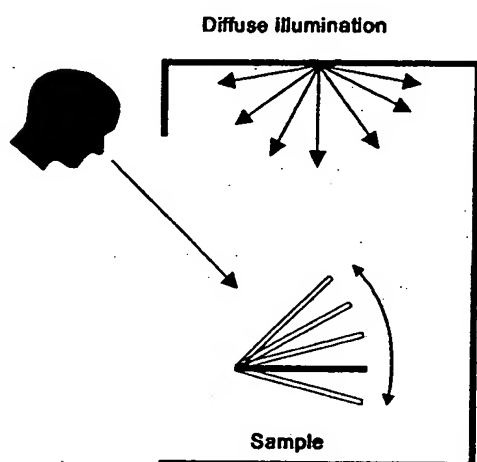


Fig. 6. Geometric arrangements for the scaling experiment.

a value of 50 GU and asked to scale the gloss of each presented sample on a scale where zero represented no perceived gloss. The observers were not given an upper limit to the scale that they used because the principle of magnitude estimation scaling is that the observers should have an open-ended scale. In practice, however, the observers did tend to use a scale value of close to 100 for the sample that was seen to be of very high gloss. Each sample was compared side by side with that reference sample having an L^* value of 68 and a gloss unit value of 43 at the measurement angle of 60° . The positions of the reference sample and the test sample were interchanged, and the testing samples presented to each observer had a different random order. This scaling method has been widely used in vision experiments and is known as magnitude estimation.

Thirteen observers, who each passed the Ishihara color vision test, scaled 84 test samples, and seven of these observers repeated their observations to give 20 ($2 \times 7 + 6$) sets of observer data. Observers were asked to hold the pair of samples with two hands at arm's length and tilt the test and the reference samples to find an angle of viewing that gave the maximum perceived gloss. This constraint-free assessment method represents the viewing method typically used for assessing gloss in industry; see Fig. 6. To preserve their integrity, the observers were

asked to wear cotton gloves to prevent fingerprints being left on the samples.

Each of the 13 observers finished his/her session in one go, and the length of time taken was between 30 and 45 min. The observers were British (four males), French (one male), Chinese (three males and three females), Korean (one female), and Tai (one female). They were all research staff or research students at the Department of Colour and Polymer Chemistry, University of Leeds, and their age range was from 24 to 45 yr.

A training session was arranged, prior to the main experiment, in which the samples from a Munsell gloss scale,¹⁷ which comprise black samples at five gloss levels, were scaled using the method to be used in the main experiment. These samples were not included in the main set of samples because they duplicated some of the NCS black samples, and the data generated as part of the training exercise were not used in the final analysis.

C. Data Analysis

As mentioned earlier, the data were gathered using the magnitude estimation method. Hence, the data are presented on a ratio scale, and the geometric mean was used as the measure of the central tendency.

Since the individual data are either logarithmic or power functions of the stimulation, they will each be related to the geometric mean function by a power transform.¹⁸⁻²¹ This automatically establishes a basis for normalizing the results of individual observers:

$$\log_{10} \bar{S}_i = a \log_{10} S_i + b, \quad (1)$$

$$S'_i = 10^{\log_{10} \bar{S}_i - b/a}, \quad (2)$$

where S_i and \bar{S}_i are the individual observer's raw data and the geometric mean calculated from all observers, respectively. The coefficients a and b (the scaling factor and intercept of line described by Eq. (1)) were obtained for each individual observer using the least-squares fitting method between the values of the individual data, $\log_{10}(S_i)$, and the values of the geometric mean, $\log_{10}(\bar{S}_i)$. The values are given in Table 2. These results showed that, although all the values of the coefficients a are close to unity, they still varied by 31%, i.e., from 0.81 to 1.12, in the magnitude of the raw data. For the values of the coefficient b , all results were close to zero. By application of the values of the coefficients a and b to each individual observer's data, those data could be normalized to a common scale.

Note that observer 4 seemed to behave differently from all the other observers. Although the values of the coefficients a and b for this observer are close to unity and zero, respectively, the associated coefficient of variation (CV), as indicated later in Table 4, is large.

Figure 7(a) shows the original observer data plotted against the geometric mean of those data; Fig. 7(b) shows the normalized individual observer's data, S'_i , plotted against the same geometric mean of the observer data, \bar{S}_i . It can be seen in Fig. 7(b) that the process of normalization serves to reduce the scatter between the two sets of data.

Table 2. Coefficients of Scaling Factor, a , and Intercept, b , for Each of the 20 Observers

Observer and Coefficient Value				
Scaling factor, a				
1	2	3	4	5
0.9582	0.9994	0.8671	0.9593	0.9514
6	7	8	9	10
0.8115	1.0254	0.9051	0.8404	0.9839
11	12	13	14	15
0.9554	1.1184	0.9057	0.9023	0.9834
16	17	18	19	20
1.0921	0.8771	0.8308	0.8173	0.8477
Intercept, b				
1	2	3	4	5
0.0194	0.0008	0.1628	0.0441	0.0463
6	7	8	9	10
0.4065	-0.0154	0.2328	0.2695	0.0020
11	12	13	14	15
0.0954	-0.2059	0.1488	0.1869	0.0108
16	17	18	19	20
-0.1880	0.1720	0.2855	0.2960	0.2220

Two methods were used to aid the comparison between any two data sets. The scatter diagram was employed to visualize their difference, and, because in many comparisons the data should be linearly related, the correlation coefficient, r , or, more correctly, the coefficient of determination, r^2 , was used as a measure of the concordance between the two data sets. The CV was also used as a statistical measure to investigate the agreement between any two sets of data, for example, x and y . CV is a measure of the distance in the y direction of the points from the 45° line in the plot of y versus x : It expresses the root-mean-square deviation of the distances of the points from this line as a percentage of the mean value of the data set. This statistic has the advantage of giving results that are independent of the size of the data set. It can be thought of as the relative percentage error and is calculated using the following equation:

$$CV = \frac{100}{\bar{y}} \sqrt{\frac{\sum (x_i - y_i)^2}{n}}, \quad (3)$$

where n is the number of samples in the x and y data sets and \bar{y} is the mean value of the y set. A value of CV equal to zero indicates perfect agreement between the two data sets being compared. The CV has a sensible meaning only when it is calculated using similar scales for the x and y data.

D. Results

Seven of the observers repeated the scaling of the 84 samples. The values of the coefficient of determination and the CV associated with the seven sets are given in Table 3.

The values of r^2 range from 0.9974 to 1.0000 with a mean value of 0.9989. The average value of CV is 3.7, indicating that, on average, the variation between the first and the second sets of data is 3.7%. This result reflects

the typical observer repeatability on scaling gloss perception. In an experiment to scale the colorfulness of a series of test colors using the magnitude estimation method, for example, corresponding values of 19% was obtained.²¹ In that experiment, the geometric mean was also used for colorfulness to represent the panel results because it was an open-ended scale, i.e., only the zero (neutral) and a reference colorfulness sample assigned a number of 40 were used, similar to the current study. The result in that study shows that scaling colorfulness is much less accurate than scaling gloss.

The lower part of Table 3 shows a similar analysis made using just the 18 neutral samples from the NCS gloss scale. It can be seen that there is not much difference between scaling all samples and scaling only neutral samples.

Another way of understanding the implications of differences in the scaling data of different observers, obtained using the same samples, is to consider the following four cases involving two observers, each scaling a series of 18 samples that progressively increase in gloss.

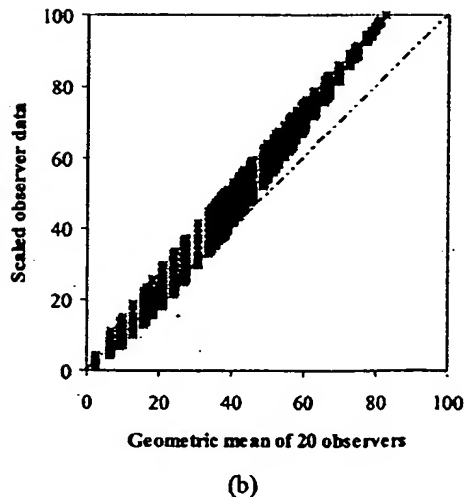
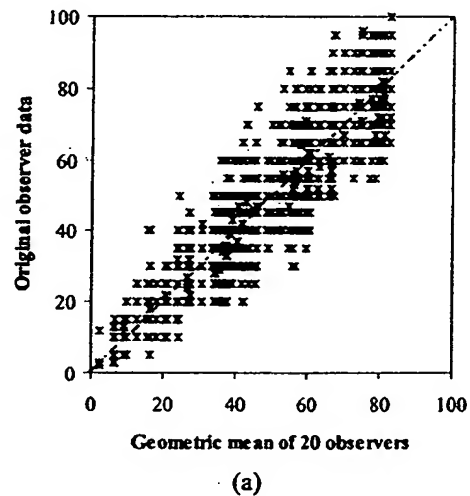


Fig. 7. (a) Original observer-scaled gloss data and (b) the scaled gloss data for each of the 20 observers plotted against the geometric mean of those 20 sets of data.

Table 3. Values of the Coefficients of Determination, r^2 , and Variation, CV, for the Seven Observers Who Repeated the Scaling of the 84 Samples^a

Observer and Coefficient Value								
All samples (84)								
	1	2	3	4	5	6	7	Mean
r ²	0.9984	0.9974	0.9977	1.000	0.9990	0.9997	0.9999	0.9989
CV	4.2	5.4	5.0	0.1	3.3	2.0	1.3	3.1
Neutral samples (18)								
r ²	0.9989	0.9980	0.9984	1.0000	0.9993	0.9998	0.9999	0.9992
CV	5.1	6.4	6.2	0.2	4.1	2.3	1.5	3.7

^aData are presented for all 84 samples and for the 18 neutral samples.**Table 4. Values of the Coefficients of Determination, r^2 , and Variation, CV, for the 20 Data Sets Compared with the Geometric Mean Data Set^a**

Observer and Coefficient Value							
r^2	1	2	3	4	5	6	7
	0.9999	1.0000	0.9981	0.9958	0.9998	0.9957	0.9999
CV	1.1	0.3	4.6	6.9	1.4	7.0	1.1
	Observer						
r^2	8	9	10	11	12	13	14
	0.9992	0.9971	1.000	0.9999	0.9987	0.9992	0.9991
CV	3.1	5.7	0.3	1.2	3.9	3.1	3.2
	Observer						
r^2	15	16	17	18	19	20	Mean
	1.0000	0.9991	0.9984	0.9967	0.996	0.9974	0.9894
CV	0.3	3.1	4.2	6.1	6.7	5.4	3.4

^aAll 84 samples were used.

1. Observer A scales the samples using a scale with values from 5 to 90 in steps of 5. Observer B scales the same samples, giving the same numbers except for one, which is scaled 5 units higher (or lower). The associated values of the coefficient of determination and CV are close to 1.00 (actually 0.9981) and 2.5%, respectively.

2. Observer A scales the samples as before. Observer B scales the same samples, giving numbers that are consistently 5 units higher. The associated values are 1.00 and 9.5%, respectively.

3. Observer A scales the samples as before. Observer B scales the same samples, giving numbers that are alternately 5 units higher and 5 units lower. The associated values of the coefficients are 0.96 and 10.5%, respectively.

4. Observer A scales the samples as before. Observer B scales the same samples, giving numbers that are equally spaced by 4 units, thus 5=5, 17=20, 41=50, 73=90. The associated values of the coefficients are 1.00 and 25.5%, respectively.

Table 4 shows the values of the coefficient of determination and CV for each individual data set tested against the geometric mean value of the 20 data sets.

The values of r^2 range from 0.9957 to 1.0000 with a mean value of 0.9894, which is commendably high. The average value of the CV is 3.4. The range of the values is from 0.3% to 7.0%. Again, these values are small.

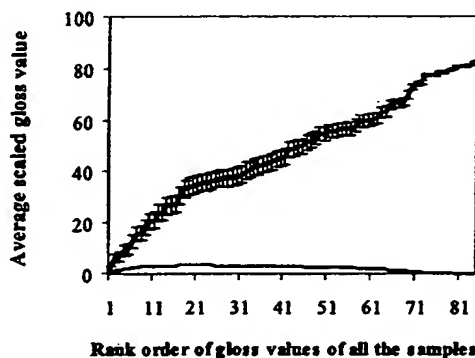


Fig. 8. Average scaled gloss value, for all 84 samples, in rank order of gloss values of all the samples. The error bars represent the associated value of ± 1 standard deviation for each sample. The values of the standard deviation are also plotted at the bottom of the graph as a function of the rank order of gloss value.

Figure 8 shows the geometric mean value of gloss for all 84 samples plotted in rank order of gloss values of all 84 gloss samples. The error bars represent the associated value of ± 1 standard deviation. The values of the standard deviation are also plotted at the bottom of the graph as a function of scaled gloss value. The latter plot shows that, after an initial rise in value of the standard deviation, the value remains approximately constant within a

defined range until a certain amount of gloss value. The low values of standard deviation are associated with samples with very low gloss and very high gloss, whereas the middle range of scaled gloss value is likely to be consistent.

Thus, a series of 84 gloss samples have been scaled by 20 observers, a mean value obtained for each sample, with an associated value of standard deviation.

6. MEASUREMENTS

Each of the 84 samples was measured using two instruments: a glossmeter and a sphere-based spectrophotometer.

A. Glossmeter

The Sheen Tri-Gloss 160/T glossmeter²² provides three readings of a sample using illumination angles of 20°, 60°, and 85°. Its configuration is similar to the generic instrument described above.⁵

B. Spectrophotometer

The second instrument that was used to measure the samples was a GretagMacbeth CE7000A sphere-based spectrophotometer. This instrument uses diffuse illumination into the integrating sphere and detects the light reflected by the sample at 8° to a normal to its surface, designated $d/8^\circ$ geometry. An attachment to the sphere has the facility either to include the light reflected by the sample at the specular angle by a plate fitted to the sphere, which is coated with a material similar to that used to coat the inside of the sphere, or to exclude this light using a so-called gloss trap. Two sets of measurements were made, the first without using the gloss-trap, specular-included (SPIN) configuration and the second with the gloss-trap-fitted, specular-excluded (SPEX) configuration. CIE X, Y, Z tristimulus values were calculated from the spectral reflectance data and the difference, ΔY , calculated between the value of the luminance factor calculated from the data that included the specular component, Y_{in} , and that calculated from the data that excluded the specular component, Y_{ex} . This should provide a measure of the light that is reflected at the specular angle. It is unlikely, however, that the geometry of this aperture complies with the specification prescribed for measuring gloss.⁴ Thus, three sets of measurements of the 84 samples were available.

Table 5. Sample Uniformity for the 84 Samples Expressed in Terms of the Coefficient of Variation

Sample Group	Number of Samples	Coefficient of Variation	
		Mean	Maximum
Original samples	45	2.8	8.3
Sprayed samples	38	8.4	15.3
Black-pile sample	1	2.0	—
All samples	84	6.0	15.3

Table 6. Sample Stability in Terms of the Correlation Coefficient, r , and the Coefficient of Variation, CV ^a

	20°	60°	85°
Set 1 versus set 2			
r	1.00	1.00	1.00
CV	2.3	0.6	0.3
Set 1 versus set 3			
r	1.00	1.00	1.00
CV	4.8	3.5	5.1

^aMeasured using the Sheen glossmeter.

C. Sample Uniformity

Some investigatory measurements were made on the uniformity of the samples, and their spatial variation in gloss value is summarized in Table 5.

Each sample was measured in five positions using the Sheen Tri-Microgloss 160/T glossmeter: top right, top left, bottom right, bottom left, and center (designated the five-point averaging method). CVs were calculated between the five measurements and their mean and over the samples in each of the four groups described in Table 5. As might be expected, the value of the CV is larger for the sprayed samples than for the original (unsprayed) samples because the spraying process, which was carried out by hand, contributed to the nonuniformity. All samples were considered acceptable by visual inspection, however, because the variation in uniformity was not visible at the optimum viewing angle for gloss detection. Indeed, the larger nonuniformity in appearance terms was that due to the gloss itself rather than the surface variability.

D. Sample Stability

Measurements were also made using the five-point averaging method to monitor the sample stability during the running of the experiment. Each of the 84 samples was measured twice prior to any observer making any observations and a third time after an interval of 1 month during which time the observations were made. They are called set 1, set 2, and set 3. Table 6 shows the values of the correlation coefficient and the CV, between these three sets of data.

Thus, there was a small amount of variation in the measurements over a short period of time, 0.6% at 60°, with larger variation over the longer time interval during which the experiment was carried out, 3.5% at 60°. It should be noted that the sample stability over time is better than the sample uniformity.

7. DATA ANALYSIS

A. Comparison between Gloss Values and Differences in the Luminance Factor

Figure 9 shows the difference in the luminance factor, ΔY , plotted as a function of the gloss value measured using the Sheen glossmeter. Data for all 84 samples are plotted. It can be seen that the relationship is not linear in that there appears to be a breakpoint in the region of 20–30 GU. The curve shown plotted on the figure com-

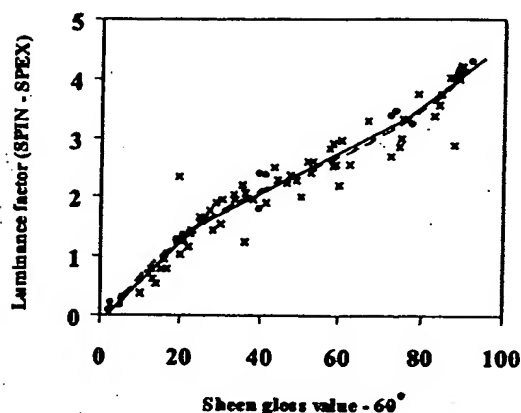


Fig. 9. Parameter, ΔY , derived from measurements made using a spectrophotometer, as a function of measurements made using a conventional glossmeter with 60° geometry. Solid curve: three-part, linear, least-squares fit. Dashed curve: cubic fit. Crosses and heavy dots represent color and neutral samples, respectively.

Table 7. Statistics of Least-Squares Lines Relating the Measurements Made Using a Glossmeter and a Spectrophotometer^a

Gloss	n	r^2	m	c
18 neutral samples				
≤ 20	8	0.9765	0.0690	-0.0926
≥ 20	10	0.9608	0.0392	0.5573
66 colored samples				
≤ 20	11	0.5576	0.0803	0.2839
≥ 20	55	0.9039	0.0365	0.5816
All samples				
≤ 20	19	0.8527	0.0653	-0.0864
≥ 20	65	0.8639	0.0382	0.4967

^aAll 84 samples and just the 18 neutral samples were considered.

prises two least-squares curves that have been calculated to give optimum values of the coefficient of determination, r^2 , resulting in a breakpoint at a gloss value of 21. The values of the associated statistics are shown in Table 7.

It should be noted that there are only a relatively small number of colored samples with a gloss value less than ~ 20 . An alternative way of considering the trend shown by the data is to fit a cubic function, also shown in Fig. 9. This yields values of the coefficient of determination of 0.9507, 0.9914, and 0.9290 for all the samples, the neutrals, and the colors, respectively. This point will be addressed in a later section of this paper.

B. Comparison between the Visually Scaled Data and the Measured Glossmeter Data

Figure 10 shows the mean of the observer-scaled gloss data, for all 84 samples, plotted as a function of the gloss values measured using the Sheen glossmeter. Again, it appears that there is a breakpoint in the data at a gloss value of approximately 20 units and possibly another at a value of approximately 80 units. These data show the same form as that demonstrated by Obein *et al.*¹⁵ and described above. To facilitate comparison with their results, we normalized the data plotted in Fig. 10 such that the

maximum value of each scale was unity, see Fig. 11, and fitted least-squares curves to the three separate sections of the data. The values of the coefficient of determination were optimized for the three sections; the resulting curves are also shown in Fig. 11, and their statistics are shown in Table 8.

It can be seen that, though the overall trends in the two sets of data are similar, the values of the slope and intercept of the fitting curves are different. As before, the data can also be fitted with a cubic function giving a coefficient of determination of 0.9746 with a corresponding value of 0.9751 for the Obein *et al.*¹⁵ data.

C. Comparison between Visual Scale Data and Differences in the Luminance Factor

Figure 12 shows the visually scaled data plotted as a function of ΔY , the difference in the luminance factor for

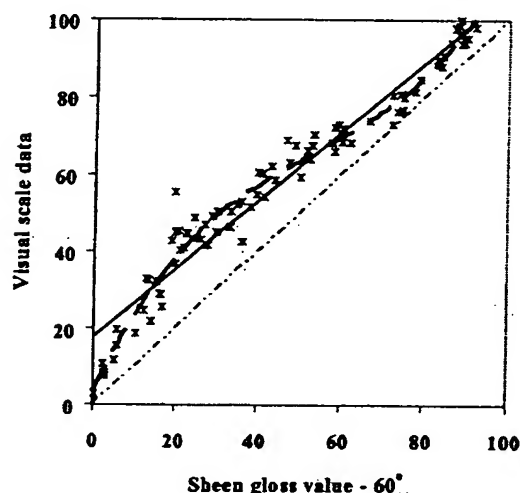


Fig. 10. Visual scale data as a function of measurements made using a conventional glossmeter with 60° geometry. Solid line: linear, least-squares fit. Dashed curve: cubic fit. (Dotted-dashed line is 45° line).

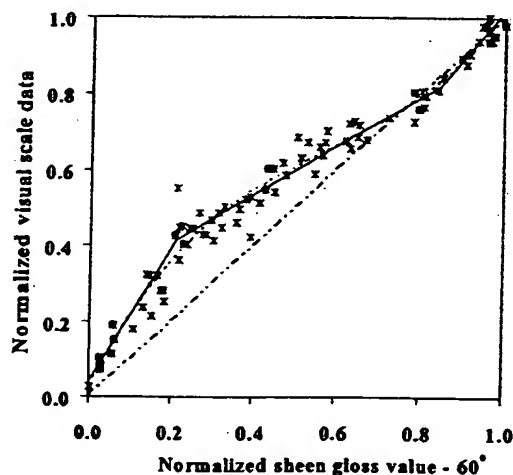


Fig. 11. Normalized visual scale data as a function of normalized measurements made using a conventional glossmeter with 60° geometry. Solid curve: three-part, linear, least-squares fit. Dashed curve: cubic fit. (Dotted-dashed line is 45° line). Crosses and heavy dots represent color and neutral samples, respectively.

SPIN and SPEX measurements. As might be implied from the comparisons presented above, there is an approximate linear relationship between these two sets of data. A least-squares fit line is also shown, and the associated statistics are given in Table 9.

Also shown in Table 9 are the statistics associated with the same data but after normalization to give a maximum value of unity for each set. The procedure enables the CV

Table 8. Statistics of Least-Squares Lines Relating the Normalized Visual Data to the Measurements Made Using a Glossmeter, Considering All 84 Samples, and Comparison Statistics for the Data of Obein *et al.*¹⁵

Gloss	<i>n</i>	<i>r</i> ²	<i>m</i>	<i>c</i>
All samples				
≤0.20	25	0.8402	1.4210	0.0508
≥0.20≤0.85	36	0.9051	0.6291	0.2861
≥0.85	23	0.7076	1.0131	-0.0156
Obein <i>et al.</i> ¹⁵				
≤0.20	3	0.9788	3.1571	0.0229
≥0.20≤0.85	7	0.938	0.5842	0.2633
≥0.85	2	1.0000	1.4344	-0.4344

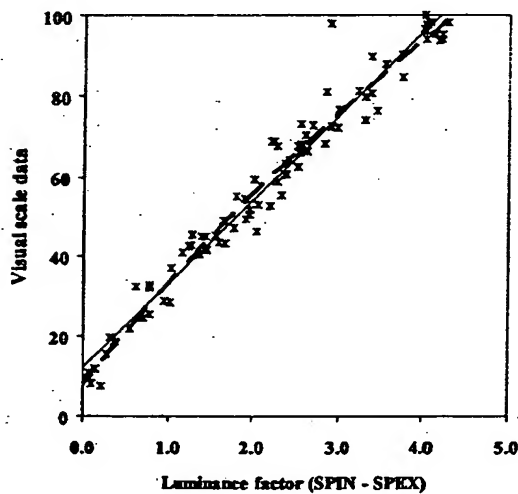


Fig. 12. Normalized visual scale data as a function of a parameter derived from measurements made using a spectrophotometer. Solid line: linear, least-squares fit. Dashed curve: cubic fit.

to be calculated because the normalization process brings both of the measures to the same scale. Applying a cubic to the data shown plotted in Fig. 12 improves the value of the coefficient of determination only marginally to 0.9634 when applied to the total data set of 84 samples, 0.9888 for the neutral samples, and 0.9484 for the colored samples.

8. DISCUSSION

From the above comparisons, it can be concluded that the two glossmeters are giving broadly similar results for measurements at 60° and 20°. The measure derived from spectrophotometric measurements is not linearly related to the gloss measurements and can be considered to have a breakpoint or, perhaps more likely, to be described as a cubic relationship. Similarly, the visual scale data are related to the measured gloss values by a combined linear function or a cubic function. This suggests, and it is subsequently found to be the case, that the visual scale data should be related to the luminance factor difference by a linear function.

Although the visual scale data are linearly related to the measured gloss values for samples of moderate to high gloss, values above ~20 GU, the gloss of samples with lower measured gloss is perceived by the observers to decrease at a faster rate than the measurements would imply. There is some spread in the data that is described by the statistics presented above; the trends suggested by the least-squares- and cubic curve-fitting routines that have been applied to the data all have reasonably high values of coefficient of determination and, where relevant, coefficient of determination that is considered robust.

The finding that the visual scale data are related to measured data via a combination of linear functions, or a cubic function, is not new. Obein *et al.*¹⁵ have demonstrated the former, and Billmeyer and O'Donnell⁸ have shown the latter. Ferwerda *et al.*¹⁰ also describe data that might be better fitted by a combination of linear functions rather than the single linear function they suggest.

The question arises as to why the better correlation is found for a measurement based on an integrating sphere as opposed to an instrument that uses specular illumination and detection. A possible answer may be that the illumination using the integrating sphere is diffuse and, while the instrument measures that light that is reflected at the specular angle, it is the only light that is diffusely

Table 9. Statistics of Least-Squares Lines Relating the Visual Data to the Measurements Made Using a Spectrophotometer^a

Data	<i>n</i>	<i>r</i> ²	<i>m</i>	<i>c</i>	CV%
Measured and scaled data					
Neutral samples	18	0.9864	20.8503	9.9003	—
Colored samples	66	0.9459	20.7561	13.4861	—
All samples	84	0.9585	20.9439	12.3455	—
Normalized data					
Neutral samples	18	0.9865	0.8965	0.0948	16.3
Colored samples	66	0.9459	0.8938	0.1296	17.8
All samples	84	0.9585	0.9013	0.1186	17.6

^aAll 84 samples were considered.

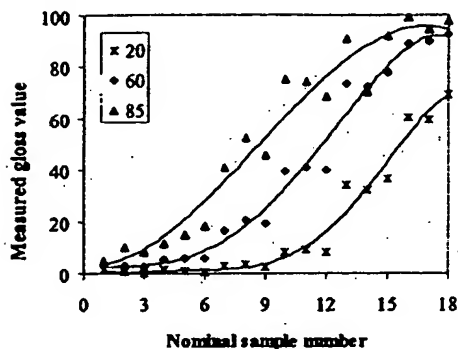


Fig. 13. Measurements of a series of samples, at three angles of illumination, as a function of the rank order of a visual assessment of their gloss. Similar to Fig. 1 but based on the method described in the paper.

illuminating the sample. This is likely to be much less than that considered in the measurement made using the conventional glossmeter.

In the opening part of this paper, a rationale was suggested as to why different angles of illumination should be used according to the level of the gloss. Figure 1 shows a set of data that attempt to support the argument that the sample should first be measured with 60° geometry and then at 20° if the gloss value is higher than 70 or at 85° if less than 10. It is of interest to plot the measured gloss data by the Sheen glossmeter on 18 neutral samples accumulated in this work as a function of the nominal sample numbers (rank order) that relate to the gloss of the samples; see Fig. 13. It can be seen that this graph shows a passing resemblance to Fig. 1; the points are fitted with cubic functions to illustrate the trend of the data. The spacing between the three data sets is, however, less than that implied by Fig. 1, and this suggests that the argument for using different angles for measurements at different levels of gloss is not strongly supported.

9. CONCLUSIONS

The following have been demonstrated in this work:

- Measurements made using a spectrophotometer, and the subsequent calculation of the difference between the luminance factors for specular-included and specular-excluded detection, do not correlate with the conventional glossmeter measurements over the entire range. At relatively low values of gloss (≤ 20 units), the rate of change falls at a higher rate.
- Visually scaled gloss data are also not correlated with measured gloss data over the entire range and show a sharper fall at low values of gloss. A cubic function better fits the data than three linear lines changing gradient at two breakpoints. This result is consistent with that found by other workers.
- Visually scaled gloss data are correlated with the measure derived from measurements made using a spectrophotometer. In this instance, a cubic fit does not give a significantly higher correlation.
- No appreciable difference was found between the visual data derived using neutral samples and that derived using colored samples. Equally, some of the samples were

constructed by spraying colored papers to provide a range of gloss values, and no appreciable difference was found between the visual data derived using unsprayed samples and sprayed samples.

ACKNOWLEDGMENTS

Wei Ji acknowledges the helpful support and discussions with his internal supervisors, G. Cui and C. Li, at the University of Leeds after the move of the Colour & Imaging Institute in the University of Derby. Also, the authors thank DigiEye PLC. for providing financial support for the project and the Swedish Colour Foundation for donating NCS samples. At the National Physical Laboratory, this work was supported as part of the National Measurement System Policy Unit Project 2.3 Measurement of Appearance.

Corresponding author Wei Ji's e-mail address is ccdwj@leeds.ac.uk.

REFERENCES

1. J. B. Hutchings, *Food Color and Appearance*, 2nd ed. (Aspen, 1999).
2. M. E. Nadal and E. A. Thompson, "New Primary standards for specular gloss measurements," *J. Coat. Technol.* **72**, 61–66 (2000).
3. R. S. Hunter and R. W. Harold, *The Measurement of Appearance*, 2nd ed. (Wiley, 1987).
4. A. H. Pfund, "The measurement of gloss," *J. Opt. Soc. Am.* **20**, 23–26 (1930).
5. ASTM D523, "Standard test method for specular gloss," (American Society for Testing and Materials, Gaithersburg, Md., 1999).
6. Byk-Gardner, Technical Note. See <http://www.bykgardner.com> (2004).
7. V. G. W. Harrison and S. R. C. Poulter, "Gloss measurement of high gloss papers," *Pap. Res.* **7**, 128–136 (1954).
8. F. W. Billmeyer and F. X. D. O'Donnell, "Visual gloss scaling and multidimensional analysis of painted specimens," *Color Res. Appl.* **12**, 315–326 (1987).
9. R. Sève, "Problems associated with the concept of gloss," *Color Res. Appl.* **18**, 241–252 (1993).
10. J. A. Ferwerda, F. Pellacini, and D. P. Greenberg, "A psychophysically-based model of surface gloss perception," in *Proc. SPIE 4299*, 291–301 (2001).
11. G. J. Ward, "Measuring and modeling anisotropic reflection," in *ACM Comput. Graphics* **26**(2), 265–272 (1992) [*Proceedings of SIGGRAPH '92*, Chicago, Illinois, July 26–31, 1992 (www.SIGGRAPH.org)].
12. Y. Sun, "A physically-based reflection model for glossy appearance," in *Proceedings of Tenth IS&T/SID Color Imaging Conference: Color Science, Systems and Applications* (Society for Imaging Science and Technology, 2002), pp. 172–177.
13. G. Obein, T. Leroux, and F. Vienot, "Bi-directional reflectance distribution factor and gloss scales," in *Proc. SPIE 4299*, 279–290 (2001).
14. G. Obein, K. Knoblauch, A. Chrismont, and F. Vienot, "Perceptual scaling of the gloss of a one-dimensional series of painted black samples," *Perception* **31**, 65 (2002).
15. G. Obein, T. Leroux, K. Knoblauch, and F. Vienot, "Visually relevant gloss parameters," in *Proceedings of the 11th International Metrology Conference*, Toulon, France, October 20–24, 2003 (www.cfmetrologie.com).
16. V. G. W. Harrison and S. R. C. Poulter, "Gloss measurement of papers—the effect of luminance factor," *Br. J. Appl. Phys.* **2**, 92–97 (1951).

17. See GretagMacbeth website: <http://www.gretagmacbeth.com> (2004).
18. S. S. Stevens, "On the psychophysical law," *Psychol. Rev.* **64**, 153–181 (1957).
19. S. S. Stevens and E. H. Galanter, "Ratio scales and category scales for a dozen perceptual continua," *J. Exp. Psychol.* **54**, 377–341 (1957).
20. C. J. Bartleson, "Changes in colour appearance with variations in chromatic adaptation," *Color Res. Appl.* **4**, 119–137 (1979).
21. M. R. Luo, A. A. Clarke, P. A. Rhodes, S. A. R. Scrivener, and C. J. Tait, "Quantifying colour appearance. Part 1. LUTCHI color appearance data," *Color Res. Appl.* **16**, 165–180 (1991).
22. See www.sheeninstruments.com (2004).